# Probing the dark side of the universe

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Though the Planck satellite has yet to return results from the cosmic microwave background, its new results show exquisite images of cold dust in our own galaxy. This image shows the galactic plane -- the line running horizontally across the image near the bottom -- and the huge clouds of cool dust that rise far above the plane. Credit: ESA and the HFI Consortium, IRAS

Advancing into the next frontier in astrophysics and cosmology depends on our ability to detect the presence of a particular type of wave in space, a primordial gravitational wave. Much like ripples moving across a pond, these waves stretch the fabric of space itself as they pass by. If detected, these weak and elusive waves could provide an unprecedented view of the earliest moments of our universe. In an article appearing in the May 21 issue of *Science*, Arizona State University theoretical physicist and cosmologist Lawrence Krauss and researchers from the

University of Chicago and Fermi national Laboratory explore the most likely detection method of these waves, with the examination of cosmic microwave radiation (CMB) standing out as the favored method.

During the past century, astronomy has been revolutionized by the use of new methods for observing the universe, but still today the origin of dark energy and dark matter is unknown. The answer to these and other mysteries may require us to probe back to the earliest moments of the Big Bang expansion. Questions of origins, such as 'how did the Universe begin,' provoke fascination and are at the forefront of ASU's Origins Project, which Krauss directs.

"Before a period of 380,000 years ago the universe was opaque to electromagnetic radiation," explains Krauss, a professor in ASU's School of Earth and Space Exploration and the physics department in the College of Liberal Arts and Sciences. "So, to explore earlier times we need to search for other observables outside of the electromagnetic spectrum. Gravitational waves interact very weakly with matter and so gravitational waves produced near the very beginning of time can make their way unimpeded to us today, providing a potentially new probe of early universe cosmology."

In 1916, Albert Einstein predicted the existence of gravitational waves. Based on his theory of general relativity, objects cause the space around them to curve. When large masses move through space, a disturbance is generated in the form of gravitational waves, but because of the weakness of gravity, astronomical amounts of matter must be moved around to generate waves on a scale that might actually be detectable.

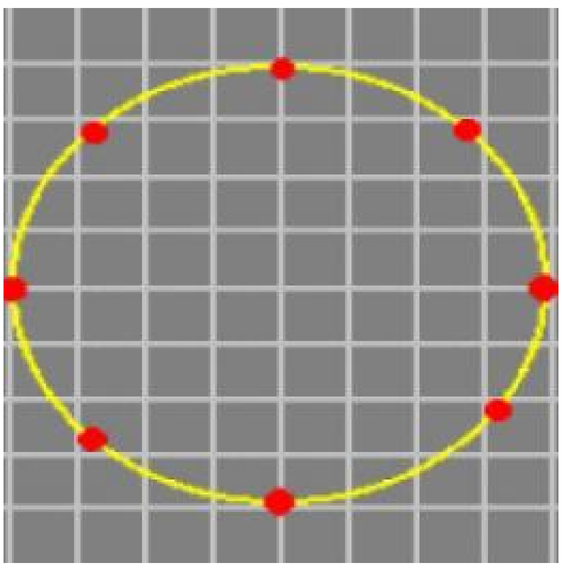
Built to feel rather than see, the Laser Interferometer Gravitational Wave Observatory, located in Livingston, La., USA, is a highly sensitive observing tool designed to find gravitational waves. Credit: LIGO Scientific Collaboration

"Imagine floating in space far away from Earth alongside two mirrors many miles apart. If a gravitational wave were propagating through space, you would see the distance between the two objects increase and then decrease rhythmically as the wave passes, perhaps by an almost imperceptible amount," explains Krauss. "As these waves propagate throughout the universe they may continue to diminish in strength, but they would never stop nor slow down since they move through matter essentially unimpeded."

"Primordial Gravitational Waves and Cosmology" was written by Krauss; Scott Dodelson, Fermi National Laboratory and University of Chicago; and Stephan Meyer, University of Chicago. In their Science review, they have determined there to be two major sources of gravitational waves: The inflation immediately after the Big Bang, and the possible phase transitions at early times. Other present-day sources may include colliding black holes or two huge stars orbiting each other.

Although these space-time ripples are imperceptible to humans, highly sensitive detectors and experiments such as the Laser Interferometer

Gravitational Wave Observatory (LIGO), located in Livingston, Louisiana, are being designed to look for precisely such waves. Gravitational radiation from the early universe can be detected indirectly through its effect on the polarization of the CMB radiation (relic radiation from the Big Bang which permeates all space). However, the current generation of direct gravitational wave detectors, LIGO included, does not have sufficient sensitivity to probe for the signals of possible primordial gravitational waves.



Spatial distortion from a plus-polarized gravitational wave travels perpendicular to the computer screen. Credit: Wm. Robert Johnston

"The greatest sensitivity to a primordial gravitational wave comes from the distinctive detailed pattern of polarization in the CMB," says Krauss. "If gravitational waves produced by either inflation or phase transitions existed when cosmic microwave background radiation was created, they would be imprinted on the CMB and be detected as polarization."

As challenging as it is to detect, the technology to build sufficiently sensitive experiments is in hand - and well worth the effort, according to Krauss.

"As we enter the second decade of the 21st century, we are poised to enter a new realm of precision cosmology, one that could provide a dramatic new window on the early universe and the physical processes that governed its origin and evolution," says Krauss. "The European Space Agency's Planck satellite was designed to image the CMB over the whole sky, with unprecedented sensitivity and angular resolution, and will provide new data on polarization within the next three to four years and with that we hope for direct observations of waves from the beginning of time."

Provided by Arizona State University

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